Investigating Contaminant Inputs via Submarine Groundwater Discharge to Coastal Waters Using Radium Isotopes

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LONG-TERM GOALS

Our long-term goal is to determine if submarine groundwater discharge (SGWD) is an important mechanism for delivering contaminants (i.e. heavy metals, organics) to harbors. We plan to accomplish this goal using a suite of naturally-occurring radium isotopes as tracers of SGWD and the dispersion of contaminants from the embayment (Buesseler/WHOI). In addition, we plan to develop a comprehensive hydrological model (Harvey/MIT) to determine the importance of SGWD in the transport of pollutants to coastal harbors.

OBJECTIVES

We will apply recently developed analytical techniques for measuring radium (^{223}Ra, ^{224}Ra delayed coincidence counting) in the study contaminant fluxes via SGWD. Recent studies suggest that groundwater may be important in the mass balance of many elements in nearshore environments and cannot be ignored in the accurate prediction of the fate of contaminants originating in marine sediments and pore waters. Even if SGWD flows are modest, pollutant concentrations in groundwater may be sufficiently high for SGWD to have an important impact on the source and fate of pollutants in coastal harbors and estuaries.

APPROACH

We spent much of the past year setting up the new radium counting facility at WHOI and designing seepage meters at MIT. To field test our methods, we chose a local study estuary (Waquoit Bay, MA) which has been well studied and is known to contain zones of high SGWD. Also, a week-long survey of our main study area Boston Harbor was completed to assess general circulation patterns in the harbor as well as the baseline distribution of radium isotopes.

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WORK COMPLETED

We acquired, constructed, and calibrated detection equipment for radium isotopic analyses. For the long-lived radium isotopes (^{226}Ra, ^{228}Ra), we purchased a Canberra Industries pure-germanium well-type gamma spectrophotometer. This detector will be modified to include an active cosmic shield thus reducing background count rates and enhancing the signal to nose ratio. This instrument will bring unique counting capabilities to ocean sciences. We also acquired the technology for short-lived radium isotope (^{223}Ra, ^{224}Ra) detection; this consisted of four custom-built delayed coincidence alpha-scintillation counters capable of low-level measurements in the lab or at sea.

This past summer, we surveyed water column and groundwater radium activities in Waquoit Bay. We also constructed 40 seepage meters to capture SGWD, and deployed these meters in Waqouit Bay. The meters provide direct measurement of the flux of SGWD, as well as water samples that are analyzed for radium concentrations.

We conducted a successful 4-day cruise in Boston Harbor during August which included measurements of four radium isotopes and salinity/temperature profiles at over 50 stations including three transects extending over 15 km from shore.

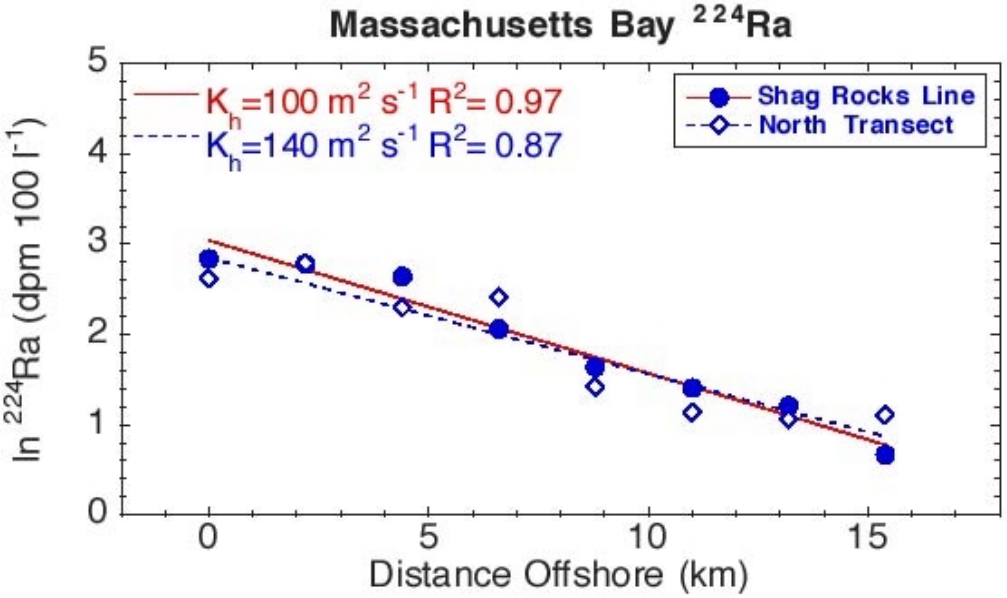

Figure 1. Radium-224 ($t_{1/2}$ =3.6 days) activities along versus distance offshore along two transects perpendicular to the entrance of Boston Harbor. The decrease in 224-Ra activitiy due to decay of the short-lived isotope can be used to calculate the offshore mixing rate (K_h) important in modelling the transport of contaminants from the Harbor.

RESULTS

Deployment of seepage meters and piezometers at the head of Waquoit Bay during several complete tidal cycles indicated that: (1) direct measurement of groundwater discharge from the meters is consistent with discharge estimated from both radium measurements in the bay and from a local hydrologic balance; (2) the tidal cycle has little effect on groundwater discharge; (3) most groundwater discharge occurs in a band between 15 and 30 meters from shore, and; (4) SGWD varies greatly on the meter-scale. The discharging water contained approximately 15% fresh water, uniformly across the study site.

The preliminary survey of radium isotope distribution in Boston Harbor indicates that groundwater discharge along its boundaries may be an important source of freshwater. Also, offshore mixing rates calculated using the short-lived radium isotope ^{224}Ra ($t_{1/2}$ =3.6 d) suggest that water-mass transport rates from the harbor entrance are less than half of typical values observed over the continental shelf (Fig. 1); the transit time for harbor water to travel approximately 15 kilometers offshore is 3-5 days (~0.03-0.06 m/s).

IMPACT/APPLICATIONS

We have successfully applied our techniques in a local estuary (Waquoit Bay) and the radium mass balance approach to calculating regionally averaged SGWD compares favorably with the seepage meter results as well an estimate based on aquifer recharge rate. The seepage meter results also indicate that classical models, based on assumptions similar to the Ghyben-Herzberg model, do not describe groundwater discharge into Waquoit Bay. Classical models do not predict the extent of freshwater saltwater mixing, or the distinct offshore band of increased discharge observed in Waquoit Bay. These behaviors may be caused by heterogeneity in sediment permeability, or may be caused by dynamical interaction of fresh and salt water at the interface.

The short-lived radium isotopes (^{223}Ra-$t_{1/2}$ =11.4 d; ^{224}Ra-$t_{1/2}$ =3.6 d) have proven to be powerful tracers of mixing rates in coastal waters. Such information can be applied to modelling the dispersion of contaminants from coastal harbors (e.g. Fig. 1).

TRANSITIONS

The nuclear detection equipment (well-type gamma detector and delayed coincidence counters) partially funded by ONR have received much use in studies other than this project. These include sedimentation studies in Lake Sisskiwit, MI and Santa Barbara Basin, CA, estimates of cross-shelf exchange in the Mid-Atlantic Bight, and nutrient and SGWD studies in West Falmouth Harbor, MA and Great Sippiwisset Marsh, MA.

RELATED PROJECTS

1 — Our radium data is being used to estimate water residence times and nutrient fluxes via SGWD in Waquoit Bay, Great Sippiwisset Marsh, and West Falmouth Harbor, MA (Rick Crawford, WHOI visiting scientist; Richard Splivalo, WHOI Summer Student Fellow).

2 — Instrumentation acquired and developed during this project has been used for preliminary measurements of cross-shelf exchange in the Mid-Atlantic Bight (Linda Rasmussen, WHOI/MIT Joint Program Student).

PUBLICATIONS

Andrews, J.A., M.A. Charette, R. Crawford, R. Splivalo and K.O. Buesseler. (1999) Utility of radium isotopes for evaluating the input and transport of groundwater-derived nitrogen to a Cape Cod estuary. EOS AGU Ocean Sciences 2000 Meeting Abstract.

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